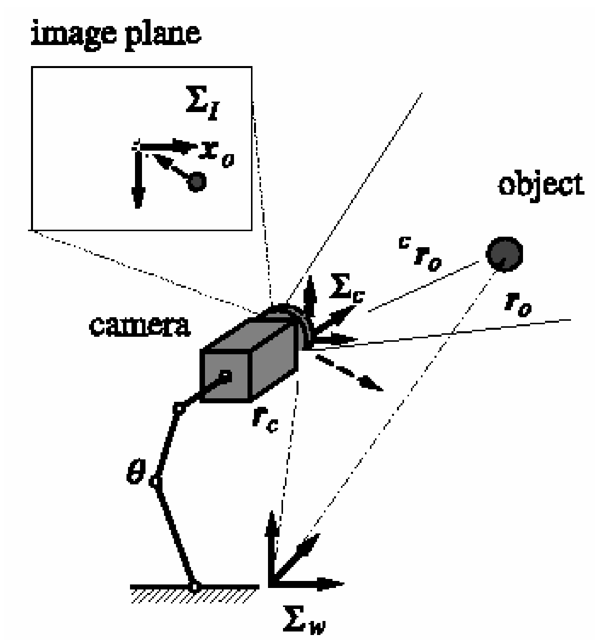
A visual servoing system for tracking of moving object

The visual servoing system introduced in this paper consists of a pan/tilt robot with 2 degree of freedom that controls a videocamera.

The aim of system is to move robot in such a way that the image of an unknown moving object attains the center of camera.

This paper also briefly describes image processing, auto detection and recognition of moving objects. The experiment with VICON system presents good results.

1. Introduction.



Robot-camera model

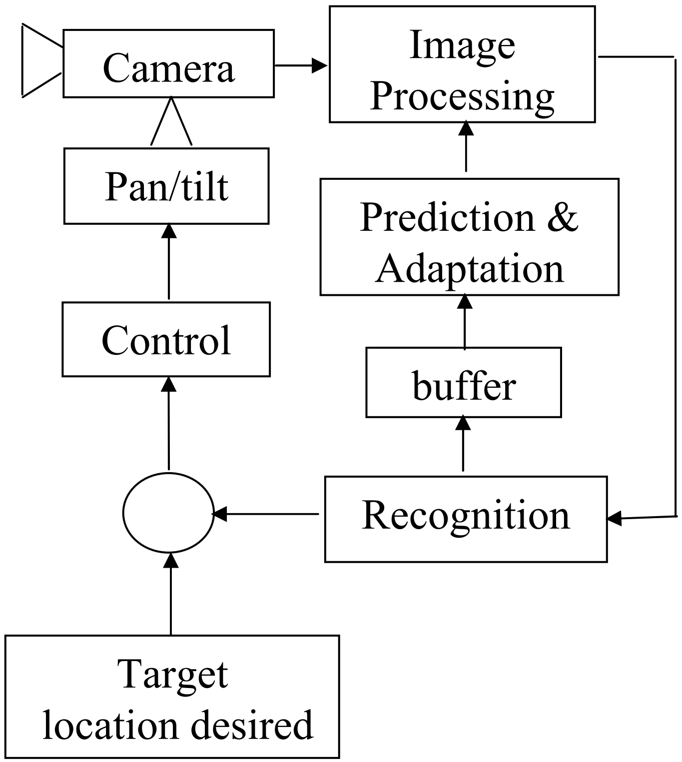
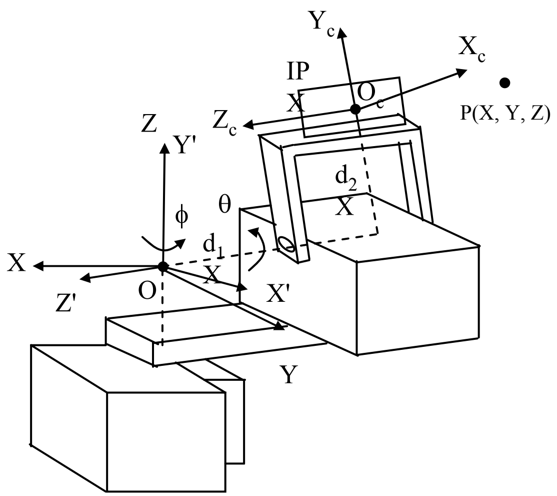
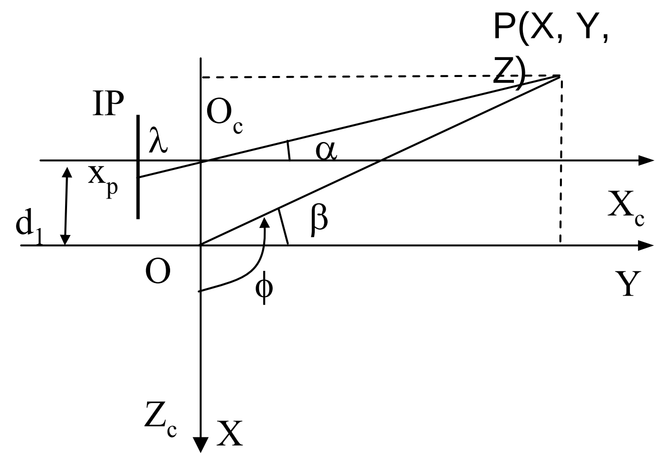


Diagram of a tracking moving system

3. Kinematic model





a. Geometric Approximations.

$$tan(\phi) = \frac{Y}{X}$$

$$tan(\alpha) = \frac{X_c}{Z_c} = \frac{Y}{X - d_1} = \frac{-x_p}{\lambda}$$

Suppose that ϕ_e is the error of making $\phi = \alpha$, then $\phi = \alpha + \phi_e$

$$tan(\phi) = tan(\alpha + \phi_e) = \frac{tan(\alpha) + tan(\phi_e)}{1 - tan(\alpha)tan(\phi_e)}$$

and

$$\phi_e = arctan\left(\frac{d_1 Y}{X^2 - d_1 X + Y^2}\right)$$

The error tends to zero when:

- $\lim_{Y \to 0} \phi_e = 0$. When control system follows acuratelly target.
- $\lim_{d1 \to 0} \phi_e = 0$. When origin O and O_c are the same point.
- $\lim_{X \to \infty} \phi_e = 0$. When target far from camera $X >> d_1 Y$.

Conclusion: admisible asuming that O and O_c are the same point.

b. Simplified Kinematic Model.

$$\phi = arctan\left(\frac{Y}{X}\right)$$

$$\theta = -arctan\left(\frac{Z}{Y}cos(\phi)\right)$$

With (x_p, y_p) is the target's centroid position in the image plane, λ is the focal length. So:

$$\phi = -arctan\left(\frac{x_p}{\lambda}\right)$$

$$\theta = arctan\left(\frac{y_p}{\lambda}cos(\phi)\right)$$

4. Prediction of target's position. Kalman filter.

The target prediction problem can be described by the Kalman filter following:

$$\boldsymbol{x}_{k+1} = \boldsymbol{A}\boldsymbol{x}_k + \boldsymbol{G}\omega_k$$
$$\boldsymbol{y}_{k+1} = \boldsymbol{C}\boldsymbol{x}_k + \zeta_k$$

where: $\boldsymbol{x}_k = [u_k \;\; \dot{u}_k \;\; v_k \;\; \dot{v}_k]^T$ $\quad \boldsymbol{y}_k = [u_k \;\; v_k]^T$

$$\boldsymbol{A} = \begin{bmatrix} 1 & T & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & T \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

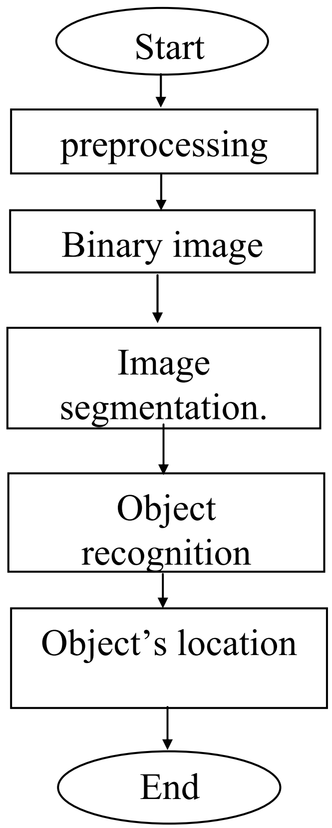
The state transition matrix

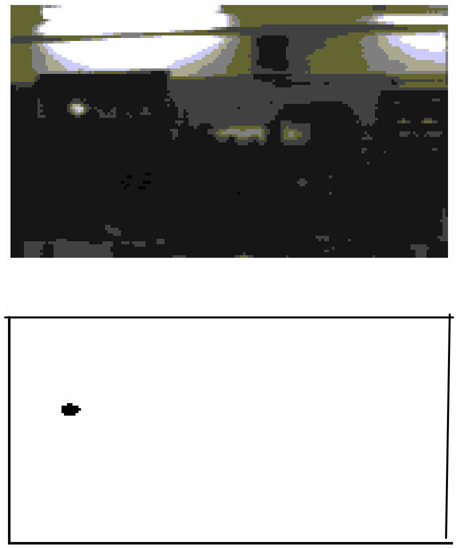
$$\boldsymbol{C} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix}$$

The output matrix

Sampling time T and noise w has a covariance **Q**, measurement ζ has a covariance **R**.

5. Recognition and tracking moving target.





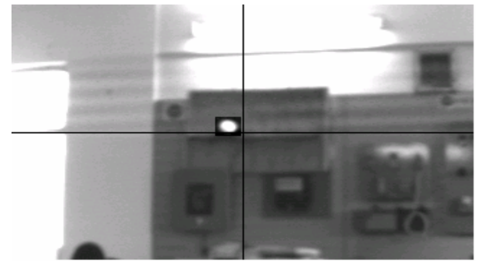
initial image and final image

6. Experimental VICON

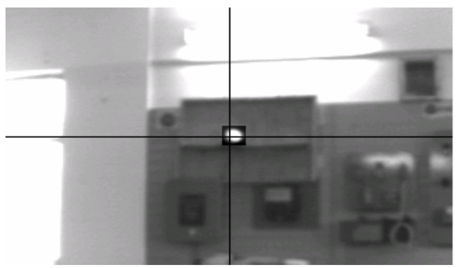
- 2DOF robot type pan and tilt by Dperception
- camera CV-M50, monochrome CCD Camera by JAI Corporation
- PC104 FrameLocker board for image digitizing
- Touchscreeen computer, 800MHz, by Nagasaki IPC Technology
- software is implemented in C and the DOS environment.

	Precision deg/step	Range deg	Max velocity deg/s
Pan	0.0129^0	$-159^0 - +158^0$	60
Tilt	0.0129^0	$-30^0 - +41^0$	60

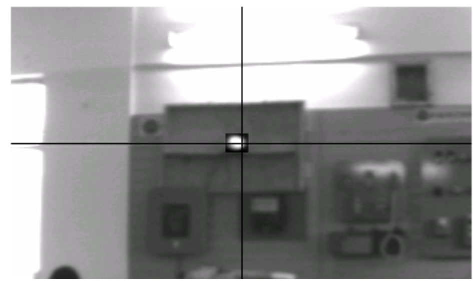
Frame 1



Frame 4

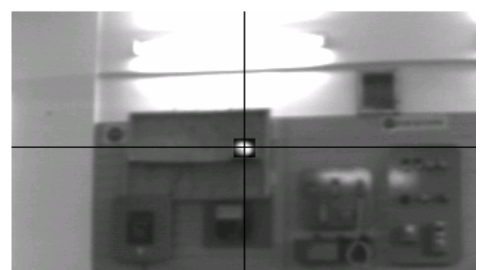


Frame 5



Frame 6

Frame 7



Frame 8

7. Conclusion.

In this paper, we have briefly presented a system for automatic tracking of moving target using computer vision. The tracking system tracked the moving target with time delay of 50msec and errors less than ±10 pixels. Nevertheless, the system reveals a limit to deal with the case of tracking fast moving object. Another study in the future will improve tracking performance of the VICON.